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Profitability of wind energy: Short-term risk factors and possible improvements

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Abstract

The wind energy industry has grown considerably in recent years. If the current rate of growth of installed capacity of 1500 MW per year continues, by 2006 Spain will achieve the objective established for 2010 in the ‘‘Plan de Fomento’’ [Plan to Promote Renewable Energies] or for 2008 in the more ambitious ‘‘Plan de Infraestructuras Eléctricas y Gasísticas’’ [Plan for Electrical and Gas Installations]. Achieving these important goals, which require significant investment, depends upon the continued stability of salaries and the willingness of banks to provide financing. Therefore, we studied those factors that had the greatest short-term impact on the economic viability of wind energy projects in Spain and we found that the inherent risk within the sector can become a real obstacle in terms of development and short-term financing. Given the possibility of carrying out financial analysis that is more exhaustive than traditionally employed methods, the various models for evaluating investment in risk conditions were studied with the aim of choosing the ideal tool that takes account of the highly fortuitous nature of wind velocity.

Keywords: Renewable energy; Wind power; Energy policy; Simulation applications

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1. Introduction

In accordance with the Kyoto Protocol, Spain is obliged to ensure that its greenhouse gas emissions (GEI) in 2012 are no greater than 15% of the total emissions in 1990, and to this end the country established the goal of producing 12% of the primary energy it consumes via renewable sources.

This means that 30.5% of the total electricity that is produced must be produced by a renewable source. If we subtract hydraulic energy production higher than 10 MW, which is estimated at around 13% of the total, the renewable sources account for 17.5% of the

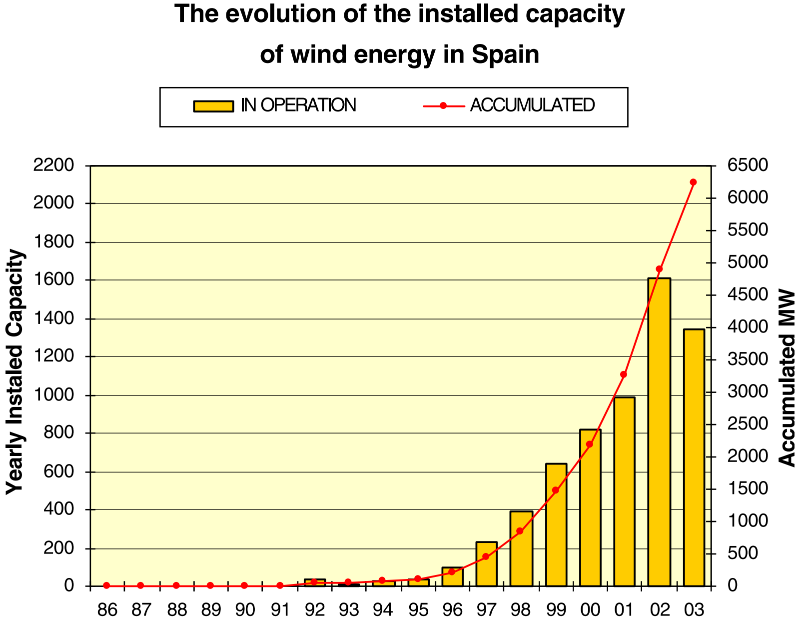


Fig. 1. The evolution of the installed capacity of wind energy in Spain.

overall national electricity production, an objective set for 2010 in the Plan to Promote Renewable Energies (PLAFER).

In 2005, with five years remaining, the energy production from renewable resources represents 7% of the total production, which is still a far cry from the aforementioned 17.5%. The installed capacity can be broken down on the basis of technology as follows:

The use of wind energy is increasing significantly, and, in terms of installed capacity, Spain is one of the leading countries in this field [1] (Fig. 1). If the current rate of growth of installed capacity of 1500 MW per year continues, by 2006 Spain will achieve the objective established for 2010 in the "Plan de Fomento" [Plan to Promote Renewable Energies] or for 2008 in the more ambitious "Plan de Infraestructuras Eléctricas y Gasísticas" [Plan for Electrical and Gas Installations].

Indeed, the Government has suggested that the objective for installed wind energy capacity by 2010 could be increased to 20,000 MW in order to compensate the low growth rate of the remaining renewable energies. This will be no easy task and will require great efforts from all those involved.

Achieving these important goals, which require significant investment, depends upon the continued stability of salaries and the willingness of banks to provide financing. Below, we outline the factors that are the short-term determinants of the economic viability of wind energy projects and detail possible improvements in their planning.

2. Profitability of wind energy and risk factors

On the basis of the analysis of the various factors that influence the profitability of wind energy installations and the predicted evolution over the next few years, calculated by the Renewable Energy Sources Producers Association (APPA) [2] in 2003, some important conclusions can be drawn.

The price of the renewable kWh has remained stable over recent years. The flexible price policy established in Royal Decree 2818/1998, which permits a choice between a fixed price or "market price + subsidy", is proving to be a determining factor in the attainment of the wind energy objectives proposed in the PLAFER as it has created an environment that encourages investors.

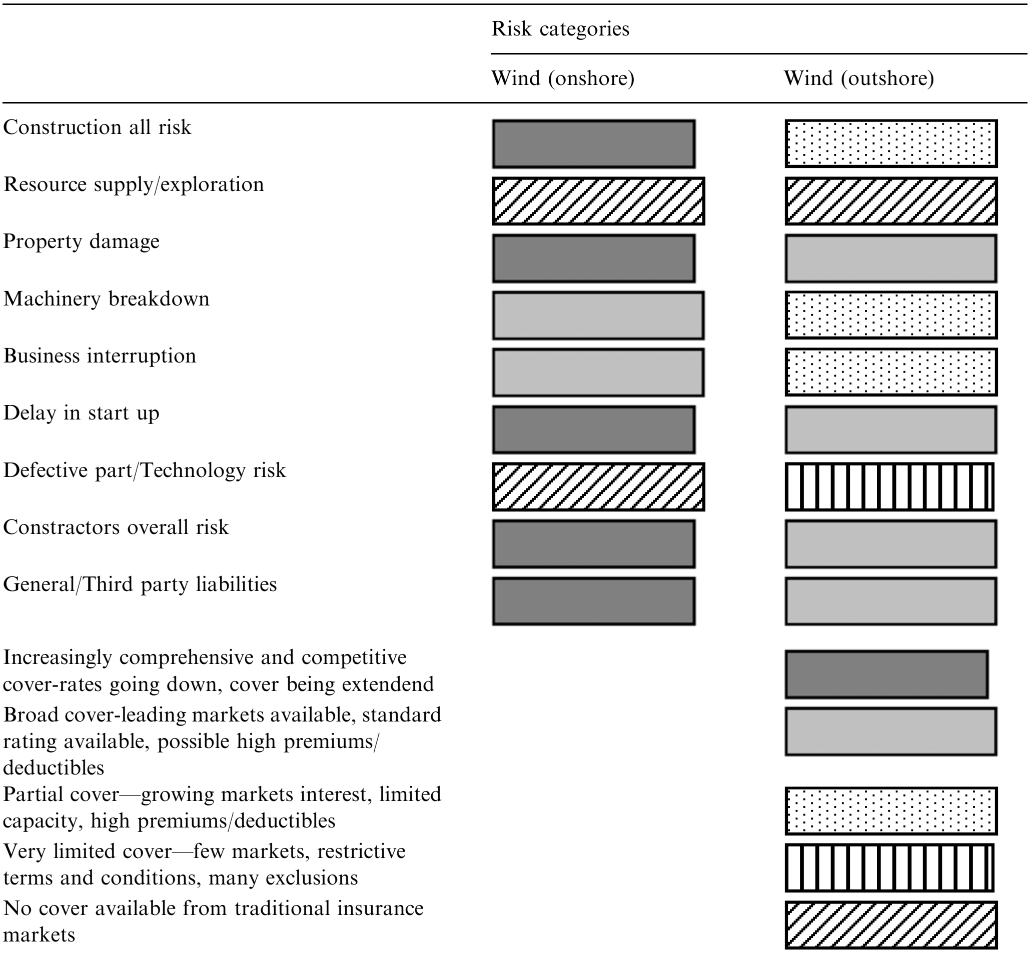
The highly fortuitous nature of the wind as a resource remains the cause of controversy. The systematic use of probability simulation models that consider the stochastic variability of wind velocity could be used to address this "unpredictability".

Until recently, much of the insurance for commercial wind energy projects, owned and developed by larger parent companies in the power sector, has been provided under the main property insurance 'package' covering the parent companies' power assets worldwide. Although providing much needed early capacity for wind energy projects, the use of (unspecialized) parent company packages did not provide adequate cover to the unique risk profile of the wind sector (especially for offshore wind projects) [3].

Those areas that are currently available for the installation of wind generators are areas with less wind, which means that we are forced to improve the performance of the generators in these areas (with the aim of achieving return on the investment) and this implies cost increases (Table 1).

Costs, wind park development periods and administrative procedures relating to wind parks have progressively increased over recent years.

Table 1
Generic RET risk transfer heat map, existing insurance products



Many of the existing parks have been in operation for five years and the manufacturer was responsible for maintenance costs during this period. The finalisation of this period draws attention to the increased costs of maintenance in subsequent years and the uncertainty that accompanies these costs, given that the manufacturers do not guarantee generator maintenance at a fixed price beyond the fifth year.

The increase to installed capacity does not merely imply network connection tasks, but also entails improvements to existing infrastructures and the construction of new lines. Whilst it might appear reasonable to expect that these new infrastructures will be paid for by the transport and electricity distribution companies, the fact is that promoters are also taking responsibility for some of these expenses.

Two years after these observations, some of the problems that arose have taken on greater significance as a result of the rate of growth of the installed capacity. Moreover, an

additional factor has come into play, modifying the panorama and contributing to the growth of the sense of uncertainty within the sector: the modification of the tax system, whereby Royal Decree 2818/1998 has been substituted by Royal Decree 436/2004 [1,4].

The subsidies for installations outlined in the second "Disposición Transitoria" [Provisional Stipulation] of the new decree, that is, the installations operating under the abolished Royal Decree 2818/1998 on a provisional basis, have decreased dramatically. In the case of wind energy we are dealing with a reduction of 14.28%.

The ensuing loss of confidence amongst banks may be a determining factor [5].

On the basis of the points outlined above, we can conclude that the ability to obtain third-party financing for wind farms will be impeded over the next few years by the existence of considerable levels of uncertainty, which forms an inherent part of these projects and may cause a saturation situation amongst the main banks. At the very least, this will imply a very stringent selection process for fund allocation.

Therefore, promoters must carefully plan and analyse their projects in an attempt to optimise the profitability/risk factor of each investment, and avoid the construction of inefficient wind farms with high levels of risk as these types of installations may become a serious obstacle to development and financing in the short term.

Therefore, we need to study the possibility of carrying out financial analysis that is more exhaustive than the analysis employed in traditional evaluation methods, given that these methods operate in conditions of certainty, with the supposition that predictions will coincide with reality.

This would entail examining the various models for the evaluation of investment in risk conditions, particularly statistical simulation methods, with the aim of choosing the ideal tool that considers the inherent uncertainty in these types of projects.

3. Investment evaluation in conditions of risk and uncertainty

Project evaluation can be defined as the assignation of a single representative index that, summarising all the financial information relating to the investment, determines the desirability of the investment project in terms of the company's willingness. A criterion must be chosen for the assignation of the aforementioned index.

Evaluation in conditions of *certainty* assumes that we have complete knowledge of the future values of the determining variables within the project (set variables).

In the case of evaluation in conditions of *uncertainty*, there is a complete lack of knowledge of the evolution of the future values of each variable (undetermined variables).

Between these two extremes we find an intermediate situation called a *risk* condition, wherein the future value of the variable is known in probabilistic terms (random variables).

Indeed, a possible definition of the risk associated with a project is the "variability of the possible result of each component that determines the profitability of the project as a result of all eventualities implied in the investment" [6].

The diverse methods of risk quantification can be classified as follows [7]:

- Approximate methods.
- Statistical methods.
- The *decision trees* and *stochastic trees* based on the sequential analysis of decisions.
- The so-called *Capital Asset Pricing Model* method [8].

3.1. Approximate methods

These methods consider risk explicitly and measure it from a subjective point of view, incorporating it into the profitability. They implicitly assume an aversion towards risk on the part of the decision-making element.

3.1.1. Sensibility analysis

Amongst the approximate methods, special attention should be drawn to *sensibility analysis*, which provided the conceptual framework for the Hertz method. Interest in this method is therefore purely conceptual.

It consists in determining the interval of probable values for each defining variable of profitability and calculating the profitability for each of these values. The interval of variance between the variables is defined subjectively and includes the independent variables.

This method allows us to determine the variables for which the result is not very sensible, thereby focusing the search for significant information, and specifying those factors that must be controlled more carefully.

3.2. Decision trees

This involves a visual technique that allows us to represent and analyse a series of future decisions in sequential order. This method is unquestionably useful when providing investment planning with conceptual form, when controlling the development of an investment over time and when attempting to clearly visualise hypothesis, consequences and choices.

The stochastic trees, wherein the random branches that grow out from the random nodes are substituted by the function of the density of the variable that determines the randomness of the aforementioned node, represent a great improvement within this technique, as is the case with the Bayesian probabilistic nets, which were specifically developed to consider the effects of dependency between variables and which appear to be a very promising tool for risk analysis at a general level [9–13].

3.3. Statistical methods

Previously, we stated that the risk within a project is derived from the variability of the outcomes that can be obtained in view of the specific eventualities involved in the project and the environment in which it unfolds. Therefore, we find a disparity between predictions and what actually happens in the future.

In the case of statistical methods, these considerations lead us to the conclusion that the defining variables within the project are of a random nature. Below we list the most frequently used methods.

3.3.1. Hillier model

This method [14] involves analysing the probability density function. This method begins by considering the cash flow and the flow of the invested capital as random variables for which the averages and variance are known. The objective is to calculate the probability density function.

Once the expected values/mathematical expectations of the cash flow, $E(Q_i)$, and the investment, $E(A)$ are known, we can calculate the expected value of the profitability as the net present value (NPV) of the project in question.

$$E(NPV) = -E(A) + \sum_{i=1}^{n} \frac{E(Q_i)}{(1+k)^i}.$$

Once we know the random variances of the variables, we can obtain the variance of the profitability:

$$\sigma^2(NPV) = \sum_{i=0}^{n} \sigma^2 \left[\frac{Q_i}{(1+k)^i} \right] + 2 \sum_{i<j} COV \left[\frac{Q_i}{(1+k)^i} + \frac{Q_j}{(1+k)^j} \right].$$

Having applied the equations outlined above and having calculated the expected value and variance of the capital value, the next step involves the attempt to discover its density function. To this end we use the central limit theory, which allows us to precisely determine the density function of the NPV under very restrictive conditions. Another useful result involves calculating the distribution parameters for the NPV when the cash flows are correlated via a first-order autoregressive stochastic process (or Markov process) [15].

In practice, when projects are complex, the derivations of the distribution of the probability of the NPV can prove tedious or impossible to obtain [16]. The simulation techniques that are explained below represent an important improvement, and therefore interest in this model is mostly of a theoretic nature.

3.3.2. Hertz model (Monte Carlo simulation)

In the sensibility analysis explained in approximate methods an interval of possible values was defined for each variable and subsequently the profitability of each of these values was calculated whilst the other variables remained constant, that is, variable by variable.

The ideal situation involves analysing the sensibility of the profitability on a comprehensive level via the joint consideration of a series of possible variations for each and every variable that affects profitability.

This is exactly what we find in the method proposed by Hertz [17]. This method is based on simulation techniques (mainly the Monte Carlo simulation method) that require the use of a computer. This is a method for solving problems numerically, based on chance, which explains its name. The method first appeared in the 1940s. The first published reference appears in a paper by Ulam (The Monte Carlo method, J. American Statistical Association, vol. 44, 1949, 335–341) [18].

The method consists in generating a series of random numbers (in this case, one number for each variable that determines the profitability to be simulated) which are transformed into another series of numbers formed by possible variable values, that is, in each iteration a value is randomly selected for each of the probability distributions of the variables and the outcome is calculated (in this case profitability) [19].

On the basis of the density functions of each variable a project investment model is constructed that defines possible relationships between these variables, and finally we discover the density function for project profitability [20].

This represents an improvement over the Hillier model in several respects: the method does not summarise the initial information on preliminary variables in terms of their

statistical characteristics; it increases the number of variables determining risk as it does not begin with possible cash flow values, but rather takes analysis back to the variables that determine these values; it always provides a density function for profitability.

The methodology is as follows:

(a) Identification of the variables that determine profitability (product sales price, investment, exploitation costs, annual production, duration of the investment, fixed costs). In the case of wind farm projects, the key variables are clearly price rates and, above all, the wind.

(b) Calculation of the density functions (or of probability in the case of random variables) of the aforementioned variables. In our case, we begin with available statistical data on wind velocity. Wind speed variation is usually described via the Weibull Distribution:

$$p(V) = \frac{c}{a}\left(\frac{V}{a}\right)^{c-1} \mathrm{e}^{[-(V/a)^c]},$$

where V is the wind velocity, c the form factor, and a the scale factor.
On the basis of the above, we can deduce that:

$$p(V \geqslant V_0) = \mathrm{e}^{[-(V/a)^c]}.$$

This equation is used to lineally adjust the empirical data and thereby obtain the Weibull form and scale factors (Fig. 2).

(c) Identify relationships of inter-dependency between the different variables.

(d) Simulation of a real situation using the Monte Carlo method. If a sufficiently large number of simulations are carried out we are able to determine the density function of the profitability via the frequency of each profitability value.

Moreover, the simulation allows us to compare alternative investment values without the need for the expected utility theory, which, despite its origins in a logical base for decision-making and despite the fact that it is the dominant paradigm amongst economists

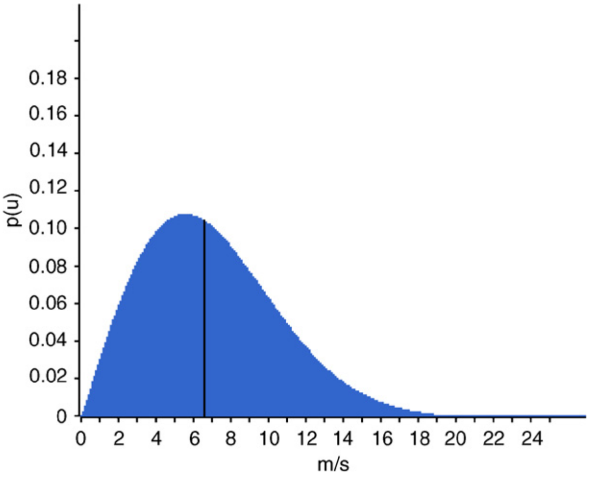


Fig. 2. Weibull distribution.

and analysts who focus on decision-making, [21], nevertheless proves of little practical value as it is very difficult to assign utility values for all possible outcomes [22].

Therefore, in most cases a simulation model is constructed for each alternative, as outlined above, in order to obtain the simulated NPV values for each project. The quality of the simulation can be improved by using common random numbers. This allows us to treat the independent observations of the profitability of each project as equal pairs when constructing the confidence intervals [23].

Thus, simulation techniques allow us to carry out an exhaustive analysis of sensibility which makes the investor aware of the nature of the risk, aids him or her in the identification of critical variables that must be more carefully controlled and reduces the number of planning errors. In short, these methods provide comprehensive knowledge on the projects, improve the quality of the decisions that are made and increase confidence in these decisions [24].

4. Conclusions

The Spanish wind energy industry has grown considerably in recent years. If the current rate of growth of installed capacity of 1500 MW per year continues, by 2006 Spain will achieve the objective established for 2010 in the "Plan de Fomento" [Plan to Promote Renewable Energies] or for 2008 in the more ambitious "Plan de Infraestructuras Eléctricas y Gasísticas" [Plan for Electrical and Gas Installations].

Achieving this goal depends upon continued stability of salaries and the willingness of banks to provide financing. The existence of high levels of uncertainty in this type of project may represent an obstacle to obtaining financing for wind farms in the short term.

Therefore, promoters must carefully plan and analyse their projects and attempt to optimise the profitability/risk factor of each investment, and avoid the construction of inefficient wind farms with high levels of risk as these types of installations may become a serious obstacle to development and financing in the short term.

Faced with the possibility of carrying out financial analysis that is more exhaustive than traditionally employed methods, the various models for evaluating investment in risk conditions were studied with the aim of choosing the ideal tool that takes account of the extremely fortuitous nature of wind velocity.

It seems clear that the statistical simulation methods are better suited to this type of project as they allow us to calculate the density function of profitability directly from the probability distributions for wind speed. Thus, more investigation needs to be carried out in this area and, bearing in mind the lack of literature that has been written up to the moment [25,26], we should apply these techniques to a standard wind farm and consider the unique features of this sector in our country.

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